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NATIONAL BUREAU OF STANDARDS REPORT

8933

REVIEW OF FABRIC FLAMMABILITY TEST METHODS

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and

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U. S. DEPARTMENT OF COMMERCE

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ABSTRACT

A review of some of the technical aspects of current textile flammability standards has been carried out. An experimental study of the test procedure of CS191-53 was made to determine the importance of certain variations in practice and interpretation among laboratories. A standard procedure was selected on the basis of the study, and a comparative classification of about fifty current clothing and bedding fabrics by CS191-53 and NFPA Standard 702 was developed. Data on the comparative heat output of the fabrics were obtained and a possible additional criterion of flame intensity outlined.

1. Introduction

The Federal Flammable Fabrics Act has been in force since July 1 of 1954, a period of more than ten years, and has generally been considered effective in achieving its purpose. Recently, however, the possibility of providing increased public protection has been raised, and various suggestions for amendment of the law have been offered. To develop a basis of information from which to judge the desirability of recommending changes in the law, the Secretary of Commerce requested a study of its operation and effectiveness to date, and a review of the commercial standards on which it is based.

In organizing such a study, it appeared that useful and definitive information could be obtained primarily from three main areas of investigation. Of these, the collection of data on actual accident experience was considered most important, but it would require facilities of a type the NBS does not presently have available. Facilities suitable for the purpose might be provided by the Public Health Service if funding support could be supplied. Some information, however, is already available from partial and regional studies and from other countries. Several years ago, an investigation sponsored jointly by the American Academy of Pediatrics and the National Fire Protection Association compiled data on nearly one hundred ignited clothing

accidents, and in California, the Fire Marshal's Office has been particularly interested in collecting pertinent records. In Great Britain, the Fire Research Station [1] has been able to obtain fairly comprehensive records for that country, and the National Research Council of Canada has made an effort to compile information through the cooperation of local fire protection units. While none of these sources provides a valid representation of the United States, the findings are of decided interest. Particularly suggestive is the general agreement among them that the fabrics involved in ignited clothing accidents are usually not of an uncommonly flammable type. Such accidents appear to result primarily from carelessness or ignorance and inexperience, and a reasonable tightening of the flammability requirements might have little effect on their incidence.

The other two areas of special interest were concerned with the development of technical data on the testing and classification of fabrics. Questions have arisen regarding the test procedure of Commercial Standard 191-53 (the primary basis for definition of hazardous flammability in the law), and furthermore, it has been suggested that the more recent National Fire Protection Association Standard 702 might be a better basis for the law than CS191-53. First, therefore, an experimental study of the test method of CS191-53 was required to determine the importance of possible variations in interpretation and equipment among different laboratories, and the need for more precise definition of the standard. Then, in addition, a comparison of the classification of representative current fabrics under CS191-53 with their classification under NFPA 702 was desirable as a basis for judging which standard might provide the more suitable definition of hazardous flammability. The present report deals with a program of experimental work on these two technical phases of the problem.

2. Study of the Test Procedure of CS191-53

The extensive application of CS191-53 since enactment of the Federal law has brought to light a number of technical questions and problems. On several points, the description of the apparatus and procedure has proved insufficiently explicit to avoid a certain amount of variation in interpretation and practice among different laboratories. In addition, the incomplete definition has permitted modifications (apparently minor, but still possibly significant) of the test equipment by the manufacturer. Although these variations have been the source of considerable concern, their actual importance in affecting the test results has been largely unknown.

With the help of comments and suggestions from the organizations most concerned in the practical application of CS191-53, the test procedure was critically analyzed to determine those points where practice among laboratories differed or a modification of procedure was proposed. The effect on the test results produced by the variations noted or suggested at these points was then determined experimentally for a representative group of fabrics. From this information, the importance of a given variable and the need for more precise definition of the standard could be judged.

Six areas of possibly significant variation were noted, some with several degrees of difference to be investigated, and this, extended to a number of fabrics, suggested a formidable amount of testing. Hence, to avoid excessively prolonged and unnecessary experimentation, a program of factorial experiments was designed for the project. After some preliminary trials to study the characteristics of the problem and determine the number of repetitive specimens required, a general plan was adopted for the several sets of tests carried out. For the most part, each set comprised three series of tests (using three different fabrics) in which the same four variables in the test procedure were compared at the same two levels of difference. Duplicate specimens were tested in each instance so that such a set of tests required 32 specimens of each fabric, with each comparison based on the averages of 16 determinations. While the plan was adjusted in some instances to study more than two levels of a variable at one time or develop a point of particular interest, care was taken to maintain a meaningful number of determinations in each comparison. In all, twenty-two series of comparisons were carried out, and eleven different fabrics were included, although several of the fabrics were used in only one series of tests.

The results of the twenty-two series of comparisons are shown in Table 1. The mean burning time for all the specimens in the series (usually 32) is given in the fourth column. The subsequent columns show the spread between the average burning times (usually of 16 specimens) obtained between the first and second of the indicated two levels of the particular variable listed in the column heading. Thus, referring to Silk I, in a series of tests for which the mean burning time was 3.32 sec., the average burning time for the specimens ignited on the surface was 0.17 sec. longer than that for the specimens ignited on the edge (that is, 3.405 sec. - 3.235 sec.), and the average burning time for the specimens with the thread 1/8 in. above the fabric was 0.26 sec. longer than that for the specimens with the thread 3/8 in. above the fabric (that is, 3.45 sec. - 3.19 sec.). Differences which proved to be significant under statistical analysis at the 95% confidence level, are indicated by an asterisk.

Brief discussions of the six variables studied are given below, outlining the sources and extent of variation experienced, the experimental approach followed, and the findings developed:

1. Oven drying.

The commercial standard stipulates that the specimens shall be dried in an oven for 30 minutes at 221 °F (105 °C). The type of oven is not specified and ovens differ widely in the time required to regain the specified temperature after introduction of a set of specimens. Hence, the total time for which specimens may be held at a considerably elevated temperature is highly variable, and the question of the possible effect of this variable on the test results has been raised.

Tests were carried out using an oven equipped with forced air circulation, which regained the specified temperature within two or three minutes after introduction of a set of specimens. The effects of holding specimens in the oven for 10, 15, 20, 30, and 60 minutes were studied. No significant effect from variations over that range was observed.

2. Desiccator cooling.

The standard requires that, upon removal from the oven, the specimens be "placed over anhydrous calcium chloride in a desiccator until cool, but for not less than 15 minutes." No maximum time limit is imposed. The rate of cooling depends on the number of specimens stacked in the desiccator, as well as on ambient conditions, and the definition of "cool" will vary with different operators. Hence, specimens may be left in the desiccator for periods ranging from 15 minutes to several hours.

In studying the effect of this variable on the test results, desiccator times of 0, 15, 30, and 60 minutes were used. The specimens tested with no time in the desiccator were removed individually from the oven and tested immediately. Silica gel was substituted as a more effective and dependable desiccant than anhydrous calcium chloride. The period of cooling in the desiccator proved unimportant after the first 30 minutes, although the specimen holders were still warm at this time. This suggests that the time required for the desiccant to absorb the moisture introduced by change of air, is the critical factor in the desiccator time rather than the temperature of the specimens and holders. This view is supported by continuous humidity records obtained from a humidity sensor hung in the top of the desiccator, which showed that the humidity in the closed desiccator closely approached its equilibrium level in about 10-15 minutes, while it required more than an hour for the holders and specimens to cool to room temperature.

3. Thread height.

The thread guides on the specimen holder, which determine the position of the stop cord over the specimen, are not precisely described in the standard and have been subject to modifications which resulted in differing heights of the thread above the fabric surface. Specimen holders of both types are in use and the effect of thread height on the test results is therefore of decided interest.

A set of specimen holders was prepared with guides which permitted threading the stop cord at various selected heights ranging from 1/8 to 3/4 in. above the specimen surface. Primarily, however, attention was centered on a comparison of the 1/8 in. and 3/8 in. heights, the two heights appearing in commercially distributed holders.

The results in Table 1 indicate that reducing the space between the thread and the fabric surface tends to increase the burning time. The important point, however, is that the thread height has a significant effect on the test results and should, therefore, be standardized and specified.

4. Flame length.

Although the length of the igniting flame is specified in the standard, the measurement of its length depends to some extent on the operator judgment and is slightly variable. In addition, the flame length is sensitive to small changes in fuel pressure and some laboratories reported difficulty in maintaining proper adjustment. Hence, information on how critical a factor the flame length might be appeared important.

The standard stipulates a flame length of 5/8 in. For the comparative study, flame lengths 1/2, 5/8, and 3/4 inches were used. The comparisons suggest that the flame length is critical chiefly as it affects the distance between the flame and the fabric, not with respect to heat output. Thus, significant differences occurred only with the shorter flame length where the tip of the flame was slightly farther from the fabric.

5. Taping of specimen.

Some lightweight fabrics are so thin that the smooth metal of the specimen holders (which may also become slightly warped) fails to grip the material. This permits the exposed area of the specimen to sag slightly farther from the igniting flame in the case of soft, limp materials, and fabrics which shrink and curl decidedly in a flame tend to draw out of the specimen holder as they burn. To prevent such behavior, the practice of securing the specimens of very thin materials to the holder by means of an adhesive tape has been suggested. Taping is sometimes used also, to hold in a reasonably smooth, flat position, the badly wrinkled specimens of materials which might be altered by pressing.

Tests were made on both taped and non-taped specimens of the same material. The taped specimens were secured to the back section of the specimen holder by means of four short strips of masking tape, one near the top and one near the bottom of each side of the specimen. Although, for the most part, taping the specimens to the holder appeared to give slightly shorter burning times, the difference did not prove significant in any instance. This indicates that taping should be an acceptable procedure in situations where it would facilitate positioning the specimen.

6. Type of ignition.

Among suggestions for change in the Federal law has been the proposal that CS191-53 be replaced by National Fire Protection Association Standard 702 as the basis for defining hazardous flammability. The two standards employ basically the same test equipment but differ in test procedure, the most notable difference being the method of igniting the specimen. In CS191-53, the igniting flame is applied to the surface of the specimen for one second, while in NFPA 702, it is applied to the edge of the specimen until ignition has occurred. This variation in ignition procedure was included in the study.

The burning times for surface ignition were significantly longer than those for edge ignition, as would be expected. The only materials which failed to show this effect were those subject to a rapid surface flash initiated by the first touch of a flame.

In addition to the difference in procedures outlines above, the comments included several suggestions for modification of the apparatus. Most frequently mentioned was a possible advantage from the substitution of an electrical timing system for the mechanically-operated stopwatch described in the standard. Some operators felt that an electrical system would provide more precise measurement and be more convenient and dependable in operation as well. To develop experience and information on the question, an electric timer was incorporated in the apparatus in such a way that both it and the stopwatch were activated by the same devices and provided simultaneous records.

The data obtained are presented graphically in Figure 1, where the difference between the reading of the electric timer and that of the stopwatch, for individual specimens was plotted against the time as recorded electrically. A consistent bias toward one device or the other would result in a preponderance of points either above or below the zero line on the vertical axis. Such an effect is evident at times less than 1.0 second, where most of the differences were negative indicating that the stopwatch gave consistently higher readings in that area. This resulted from the fact that the mechanical system could not register times less than the duration of flame application which was set at 1.0 second. Otherwise, the data indicate no consistent bias, particularly at the burning times of primary interest. At burning times longer than 9 or 10 seconds slight trends may be suggested, but, with most of the differences less than ±0.1 second, they are scarcely significant. Hence, it would appear that either timing method may be used satisfactorily if proper adjustment is maintained. The resolution with the electric timer is much finer, of course, but the need for this precision is questionable.

Another point on which some question was raised involved the positioning of the specimen in the specimen holder. The usual practice of most operators appears to have been to place the lower end of the 6-in. specimen even with the lower end of the back plate of the specimen holder. Inserted thus, the igniting flame should impinge on the surface of the material at a point 1/2 in. from the lower end of the specimen. However, this 1/2 in. spacing (which may be further reduced by only slight deviations in flame or specimen adjustment) is small enough that fabrics subject to severe shrinkage in a flame may draw the edge up to produce essentially edge ignition. Throughout the present study, the specimens were positioned about 1/8 in. lower in the holders in order to slightly increase the distance between the point of flame impingement and the specimen edge. This was accomplished by cutting the specimens 6-1/4 inches in length and positioning the upper end even with the top of back plate.

One of the modifications which have developed in the apparatus since the original design, appears in the rack which supports the specimen holder during test. In the early machines, the metal support on which the bottom of the specimen holder rests was a continuous bar running across the full width of the rack. In the currently produced machines, however, the bar has become discontinuous, supporting the specimen holder at the corners but leaving the center open. While these arrangements are equally satisfactory for support of the holder, the conditions of air flow around the bottom edge of the fabric specimen will be affected by the presence or absence of the partial obstruction of the bar across the center of the rack. Although the effect of this modification was not studied extensively, sufficient comparison was made to show that it does influence the burning times of some fabrics, and should be standardized in all machines.

3. Comparative Classification Under CS191-53 and NFPA 702

To develop information on the comparative classification of current fabrics by the two standards CS191-53 and NFPA 702, about fifty materials were purchased at various stores on the ordinary retail market. Inasmuch as proposals have been made to extend coverage of the Federal law to bedding materials, representative blanket and other bedding fabrics were included, along with a wide range of clothing fabrics.

The test method itself is very similar for the two standards. They employ the same apparatus and the procedures differ primarily in the manner of igniting the specimens of smooth-surfaced fabrics (without nap, pile, or other type of raised-fiber surface). In CS191-53, the igniting flame is applied to the surface of the specimen for one second only, whereas in NFPA 702, the igniting flame is applied to the edge of the specimen as long as necessary to achieve ignition. Both standards require the one-second surface application of the igniting flame for fabrics with a raised-fiber surface.

The igniting procedure was the only significant difference in the methods used in developing the comparative classification of fabrics. Other parts of the test method were standardized on the basis of the study reported above. The oven conditioning of 30 minutes at 105 °C was retained and a uniform period of 30 minutes in the desiccator was adopted. Specimen holders with a bent-pin type of thread guides providing a uniform thread height of 3/8 in. across the specimen were used. This was facilitated by the installation of a new thread guide in the cabinet above the spool. The practice of positioning the specimen 1/8 in. lower in the holder was continued. The support rack on which the specimen holder rested during the test, was used with a discontinuous support bar as provided in currently-produced machines. The flame length was maintained at 5/8 in. and checked frequently, with particular care to avoid variations toward a shorter length. Use of the electric timer concurrently with the mechanical stopwatch was continued.

Because of the number and diversity of fabrics involved, the program offered an excellent opportunity to develop information on the heat produced by the burning of different fabrics, as well as their comparative classification. Flame intensity is commonly recognized as an important element in hazardous flammability, but it has proved difficult to gage, and it appeared that data on the heat output of the various materials might be helpful. As a heat sensor, a copper plate 4 in. square, 0.022 in. thick, and weighing 51.5 grams, was installed in the test cabinet above the upper end of the specimen. It was hung in a horizontal position 1/4 in. below the top of the cabinet and did not alter the test conditions within the cabinet. A #28 gage (.0126 in.) chromel-alumel thermocouple attached to the plate permitted recording a continuous trace of the plate temperature. From the known characterestics of the plate and its increase in temperature, the heat absorbed by the plate may be calculated, and for comparative purposes, it may serve as a measure of heat output of the specimen. In comparing data obtained with the same sensor, however, the calculation is unnecessary, since the increase in temperature is the only variable among the determinations. Assuming linearity over the temperature ranges involved, millivolt changes in the thermocouple signal will serve to represent changes in the plate temperature.

The fabrics included in the comparison are listed in Table 2 together with the data obtained using the two different ignition procedures. The values shown for burning time and millivolt change are, in most instances, the average for six determinations. To obtain heat output readings for those materials which did not ignite during the one-second surface application of the igniting flame, ignition was forced by manually continuing the flame application until ignition occurred. Most of the fabrics with a raised-fiber surface would not ordinarily have been tested differently or have different values under the two standards, but in the interest of developing as much comparative information as possible, the two types of ignition were continued through that class of fabrics also. Hence, the data shown under NFPA 702 for raised-surface fabrics were obtained with edge ignition just as those for the smooth-surfaced fabrics.

Predictably, the burning times obtained with edge ignition were, in most cases, shorter than those obtained with surface ignition. On brushed surface materials which showed a rapid surface flash, however, it made no difference how the flame was applied, and for lighweight materials which ignited quickly, the effect was generally small. On the basis of the present respective definitions of hazardous flammability, NFPA 702 and the Federal law provided almost identical classifications of the materials studied. One borderline silk was recorded as failing the Federal law definition by a slight margin while it just barely passed the NFPA 702 definition, but the variation in a fabric itself is such that a borderline material may fall on either side of a precise defining line in repeated trials. The results of this study indicate, therefore, that the classification of fabrics as hazardously flammable would be changed little, if any, by making NFPA 702 the basis of the Federal law.

In addition to the classification for fabrics, the NFPA standard provides requirements for non-textile articles of wearing apparel (not covered in CS191-53) and this has been cited as a special recommendation for its inclusion in the Federal law. There is a general concensus that such items should be subject to control, but the developement of a suitable method of testing articles of such varied size, shape, and composition has proved extremely difficult. Several suggestions have been made for possible test procedures, besides that described in NFPA 702, and some work with various types of masks and other costume items has been carried out. Definite recommendations have not yet been developed, however, and continued study of the problem is planned.

4. Discussion of Data on Heat Output

A graphical presentation appeared appropriate for consideration of the data obtained on the heat produced by the burning specimens. Figure 2 shows the average heat sensor output plotted against the average burning time, using the results obtained with the surface ignition procedure of CS191-53. For the materials which did not ignite from the ususal one-second flame application, the data resulting from ignition forced by continued application of the flame were used. To help in study and analysis of the data, broad groupings of the fabrics are indicated by identifying symbols.

Although a number of varying factors (special finishes, novelty weaves, quilted laminations, etc.) entered into the results, some general indications may be noted. Thus, under the particular conditions of the test, materials entirely of Dacron or of silk appeared relatively low in heat output. There is also a general indication that, among fabrics without a raised-fiber surface, acetates or blends predominantly acetate, tended to produce somewhat more heat than cottons and rayons which showed a similar rate of flame spread. Among the fabrics with raised-fiber surface, those with acrylic brushed or pile surface did not show the rapid flash of the cottons and rayons although their heat output was comparable or greater.

A study of the graph suggests that, should it be considered desirable, heat measurements of this type could serve as part of the definition of hazardous flammability. The ratio of heat output to burning time could be used as an added criterion, with the requirement that values for the ratio higher than those represented by a selected line (such as the dashed line shown) would class a material as hazardously flammable. This would include the factor of flame intensity in the definition on a broader basis than at present, and would somewhat strengthen the requirements for acceptability. In the case of brushed cottons and rayons, for example, a slightly lighter brushing, to shift the burning time to around 4.5 seconds, would no longer be enough to achieve acceptability. If desired, the criterion could be extended on down to zero time for fabrics with a raised-fiber surface, providing a requirement perhaps a little more severe than the present criterion of base fabric ignition.

In Figure 3, the heat sensor output is plotted against the fabric weight. The generally linear relation suggests that fabric weight might reasonably represent the heat output, and hence that actual heat determinations might be unnecessary. In Figure 4, the fabric weight (rather than heat sensor output) has been plotted against burning time. It is evident that a requirement limiting the ratio of fabric weight over burning time to values no greater than those represented by the dashed line in Figure 4 would provide almost the same differentiation of the fabrics studied as that provided by a criterion based on the heat sensor measurements shown by the dashed line of Figure 2. For fabrics which show a "timed-surface flash" that fails to ignite the base fabric there is, of course, little relation between the heat output of the surface flash and the weight of the whole fabric. For this group, therefore, the fabric weight/burning time ratio could not properly represent the heat output/burning time ratio and, unless actual heat measurements were made, the criterion would not suitably replace that of base fabric ignition.

In addition to the determinations in the inclined flammability tester, heat measurements were made on about 30 of the fabrics by another method which had been used in previous work [2]. This method used equipment similar to a British design developed for the measurement of heat supplied to an adjacent surface by a burning fabric. A specimen 30 inches long and 4 inches wide was suspended vertically, 1/2 inch from an asbestos millboard-back panel and held in place by six wire cross-lacings about 4 inches apart. The specimen was ignited across the lower end and allowed to burn freely. Cylindrical copper plugs, 1/2 inch in diameter and with thermocouples attached to the back, were set flush in the millboard panel at several heights and the heat dosage received by a given plug could be calculated from its known characteristics and its recorded temperature rise. For a general comparison with heat measurements obtained in the CS191-53 tests, however, the change in the electrical output of the thermocouple itself is sufficient, and, in Figure 5, the milivolt signal recorded in the inclined method was plotted

against that recorded by a copper sensor plug located about 14 inches below the top of the specimen. A close correlation could not be expected since the two methods involve different types of exposure under different conditions, but the relation between them appears to be roughly linear. This tends to support to some extent the validity of both methods as acceptable means of gaging a basic characteristic of the fabric.

5. Summary

In the interest of effective public protection, a review of the operation of the Flammable Fabrics Act and the adequacy of textile flammability standards was requested by the Secretary of Commerce. While facilities for collecting information on actual accident experience are not presently available, technical phases of the review have been carried out. An experimental study of the test procedure of CS191-53 was made to determine the importance of certain variations in practice and interpretation among laboratories and the effect of various proposed modifications. On the basis of this study, a standard procedure was selected for continued work with the method. Varying only the manner of ignition, to conform to CS191-53 and NFPA Standard 702, respectively, comparative data were developed by the two methods on current clothing and bedding fabrics. The NFPA Standard 702 provided almost the same classification of the approximately fifty fabrics studied as that of the Federal law, on the basis of the present respective definitions of hazardous flammability. In conjunction with developmnet of the comparative classification of the fabrics, measurements of the comparative heat output were made which suggested a possibly useful criterion of flame intensity.

6. References

[1] Lawson, D. I., "Fire Accidents - The Contribution of Some Textiles," Research Vol 11 (1958); pp. 126-133.

[2] Sandholzer, M. W., "Effect of Fiber Composition on Textile Flammability," NBS Technical Report No. 7339. (Sept 1961)

Table 1. Influence of Procedure Variables on Results

Fabric: Material	Fabric: Construction	Fabric: Weight	Mean Burning Time	Point of Ignition (edge-surface)	Thread Height (1/8-3/8")	Taping Specimen in Holder (Taped-Not taped)	Flame Length (1/2-5/8")	Flame Length (5/8-3/4")	Flame Length (1/2-3/4")	Strip on Support Rack (Strip-No strip)	Oven Time (in minutes) (10-20)	Oven Time (in minutes) (15-30)	Oven Time (in minutes) (30-60)	Desiccator Time (in minutes) (0-15)	Desiccator Time (in minutes) (15-60)	Desiccator Time (in minutes) (30-60)
		oz/yd²	sec	sec	sec	sec	sec	sec	sec	sec	sec	sec	sec	sec	sec	sec
Silk I (sheer)	Plain weave	0.6	3.32	-0.17 *	0.26 *	-0.11	0.18 *									
			3.23	-0.26 *	0.26 *	-0.01					0.01					0.05
Silk II (Organza)	Plain weave	0.7	3.90	-0.33 *	0.38 *	-0.05	0.20 *									
Silk III	Plain weave	1.3	6.14	-0.33 *	0.36 *	-0.07	0.40 *									
Cotton I (organdy)	Plain weave	1.5	3.77	-1.25 *	0.29 *	-0.07	0.21 *									
			3.62	-1.38 *	0.38 *	-0.08		0.01								
			3.59	-1.09 *	0.33 *				0.21 *							
Cotton II (Batiste)	Plain weave	1.8	6.84		0.37 *	0.00						-0.02	-0.08	-0.28*	-0.60*	
			5.00	-3.17 *	0.35 *	-0.04					0.03					-0.09
Acetate I (sheer)	Novelty weave	1.7	3.81	-0.23 *	0.34 *	-0.04	0.38 *									
Acetate II (Taffeta)	Plain weave	2.8	5.37		0.12	0.03		-0.11		0.33 *						
			5.21	-0.88 *	0.18 *	-0.13					-0.04					0.01
Rayon I (Chiffon)	Crepe weave	1.0	2.95	-0.80 *	0.37 *	-0.18	0.25 *									
			2.72	-0.70 *	0.32 *	-0.05		-0.00								
			2.81	-0.83 *	0.36 *				0.52 *							
			3.08		0.26 *	-0.06		0.05		0.16 *						
Rayon II (Blanket)	Plain weave brushed	5.8	1.01	0.01	0.03	0.03	0.10									
			0.91	0.00	0.11 *	0.01	0.03									
			0.92	-0.01	0.12 *	-0.05		-0.01								
			0.91	0.02	0.12 *				0.02							
Rayon Pile - Cotton back	Woven back	13.4	2.60	-0.05	0.95 *	0.14	0.04									
Orlon Pile Cotton back	Knit back	9.2	16.33	-5.64*	2.16 *	0.29	0.09									

* Results significant at a confidence level of 95% or greater

Table 2. Comparative Data on Fabric Materials

Fabric Description			CS191-53 (Surface Ignition)			NFPA702(edge Ignition)	
			Burning Time				
Identifying Designation	Fiber Content	Weight	1 sec.Exposure	Forced Ignition	Heat Output	Burning Time	Heat Output
		oz/yd^2	sec	sec	mv	sec	mv
			Fabrics with raised-fiber surface				
Flannelette	Cotton	3.7	DNI	16.8	0.662	7.0	0.627
Receiving Blanket I	Cotton	5.7	1.1		0.838	1.1	0.851
Receiving Blanket II	Cotton	6.0	0.9		0.730	0.9	0.751
Bed Blanket I	Rayon, 94% Nylon, 6%	5.8	0.9		0.719	0.9	0.752
Bed Blanket II	Rayon, 74% Cotton, 20% Nylon, 6%	6.3	0.9		0.898	0.9	0.956
Torch Sweater	Rayon	9.0	0.9		1.269	0.9	1.405
Pile Fabric I	Rayon pile Cotton back	13.4	1.8 (TSF)		0.228	20.6	1.433
Pile Fabric II	Acrylic pile cotton back	8.4	16.4		1.459	13.0	1.489
Pile Fabric III	Acrylic (Orlon) pile Cotton back	9.2	19.6		1.777	14.1	1.690
Crib blanket	Acrylic	9.7	27.4 (1)	22.7	2.278	21.0	2.390
Tufted I	Cotton	7.6	2.1		1.029	2.5	0.999
Tufted II	Cotton	9.4	4.7		1.296	7.2	1.263
Tufted III	Cotton	16.3	7.0		1.822	7.0	1.787
			Fabrics without raised-fiber surface				
Chiffon	Rayon	1.0	2.9		0.214	2.4	0.231
Organdy	Cotton	1.5	3.9		0.316	3.1	0.328
Batiste	Cotton	1.8	7.8		0.342	3.6	0.334
Novelty I	Rayon	3.3	8.6		0.614	5.7	0.642
Shantessa Print	Cotton	3.9	DNI	20.5	0.492	5.8	0.595
Percale sheet	Cotton	3.9	DNI	20.6	0.626	6.4	0.613
Byrd cloth	Cotton	4.8	DNI	12.0	0.806	7.8	0.806
Stretch Poplin	Cotton, 50% Zantrel Rayon, 50%	6.2	DNI	24.4	0.980	9.4	1.011
Bengaline	Rayon warp cotton fill	6.5	DNI	26.1	0.858	11.1	0.927
Stretch duck	Cotton	6.7	DNI	28.9	1.070	10.9	1.098
Boucle	Rayon, 62% Acetate, 38%	7.3	DNI	31.0	1.065	11.2	1.130
Monks Cloth	Cotton	8.1	DNI	24.2	1.252	12.5	1.255
Army sateen	Cotton	8.6	DNI	37.8	1.333	16.0	1.310
Novelty II	Rayon, 94% Silk, 6%	9.0	DNI	40.6	1.019	13.3	1.191
Raincoat	Cotton warp Acetate fill	6.3	DNI	22.6	1.072	10.5	1.038
Quilted pad	Cotton	9.6	DNI	26.8	1.380	16.0	1.356
Silk I	Silk	0.6	3.2		0.102	3.0	0.102
Silk II	Silk	0.7	3.6		0.115	3.5	0.111
Silk III	Silk	1.3	6.4		0.176	6.2	0.189

Table 2. Comparative Data on Fabric Materials (concluded)

Fabric Description			CS191-53 (Surface Ignition)			NFPA702(Edge Ignition)	
			Burning Time				
Identifying Designation	Fiber Content	Weight	1 sec.Exposure	Forced Ignition	Heat Output	Burning Time	Heat Output
		oz/yd^2	sec	sec	mv	sec	mv
Fabrics without raised-fiber surface (concluded)							
Novelty III	Acetate	1.7	3.9		0.347	3.6	0.376
Sheer	Dacron	2.0	13.2		0.219	12.7	0.202
Print I	Acetate, 60% Cotton, 40%	2.4	6.5		0.513	4.5	0.487
Print II	Dacron, 65% Cotton, 35%	2.6	DNI	8.9	0.459	5.1	0.454
Lining fabric	Acetate	2.8	5.2		0.524	5.3	0.510
Dotted Swiss	Dacron, 65% Cotton, 35%	2.8	DNI	9.9	0.502	5.6	0.512
Lined Lace I (lock-lined)	Acetate lining Cotton lace	5.1	8.7		1.044	7.1	1.030
Lined Lace II	Acetate lining lace (wool, 50% (rayon,50%	7.1	DNI	15.9	1.368	12.1	1.497
Novelty IV	Rayon, 60% Linen, 25% Wool, 15%	7.9	DNI	21.6	1.315	13.0	1.386
Taffeta	Acetate	3.5	6.2		0.570	5.4	0.536
Net	Dacron	0.8	5.9(2)		0.074	8.6(2)	0.050
Quilted robe I (face)	Acetate cover and lining, polyester pad	5.9	14.1		0.888	12.5	0.829
Quilted robe I (back)	"	5.9	14.8		0.971	9,9	0.945
Quilted robe II (face)	Acetate cover and lining, polyester pad	6.8	18.8		1.110	11.9	0.937
Quilted robe II (back)	"	6.8	18.9(1)	15.4	1.112	10.7	1.024
Quilted robe III (face)	Acetate cover and lining, acetate pad	5.1	DNI	11.6	0.825	9.3	0.791
Quilted robe III (back)	"	5.1	15.0(1)	9.6	0.722	8.7	0.639

DNI - did not ignite during the 1-sec. flame exposure
TSF - timed surface flash which burned the thread but did not ignite the base fabric
(1) - value based on the 3 or 4 specimens which ignited; the remaining 2 or 3 specimens required forced ignition with an average time as shown.
(2) - flame travel erratic and usually self-extinguished; surface ignition values are averages for 5 out of 12 specimens tested, edge ignition values are averages for 2 out of 12 specimens tested.

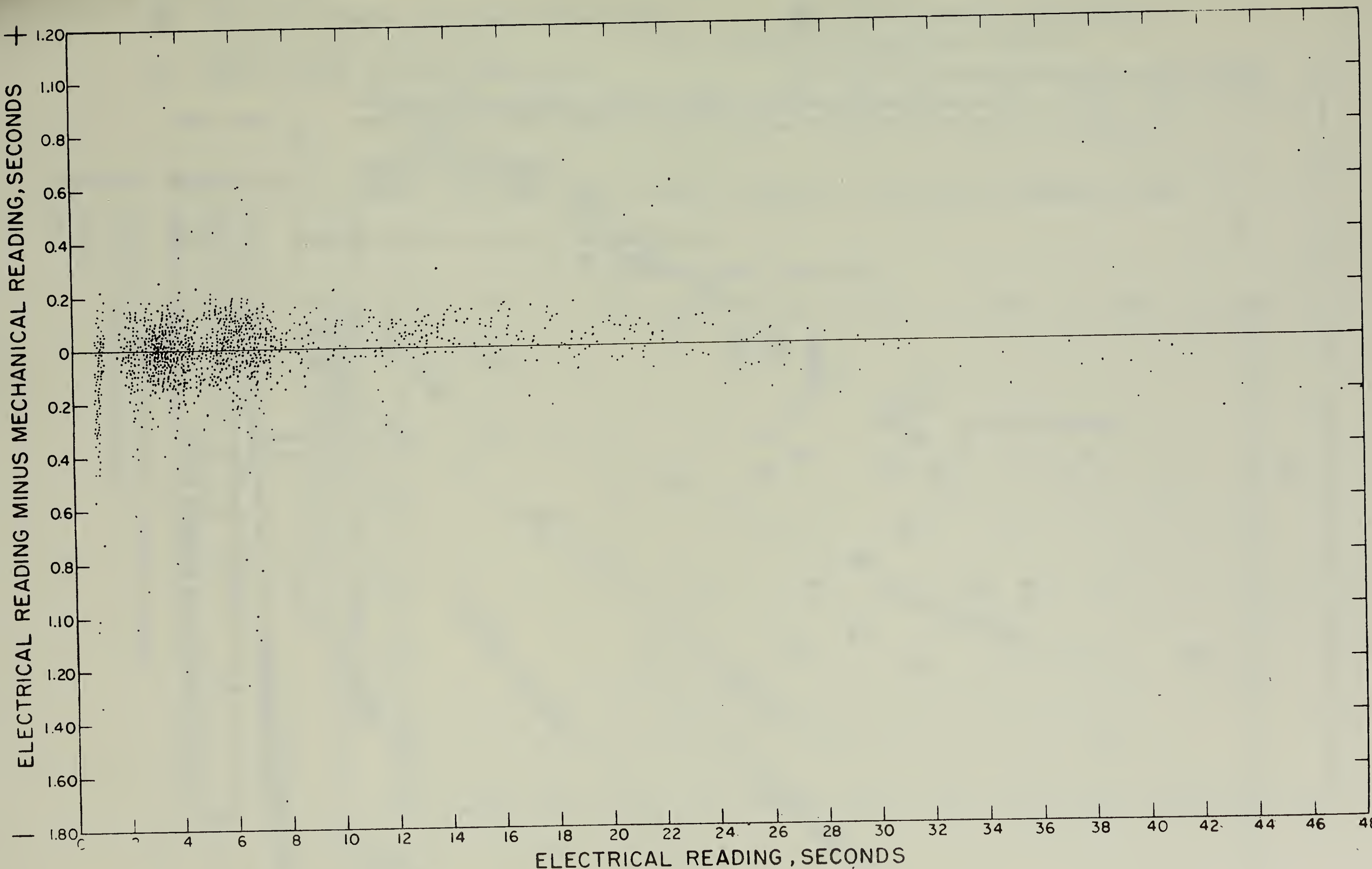

FIGURE 1. RELATION BETWEEN ELECTRICAL AND MECHANICAL TIMING

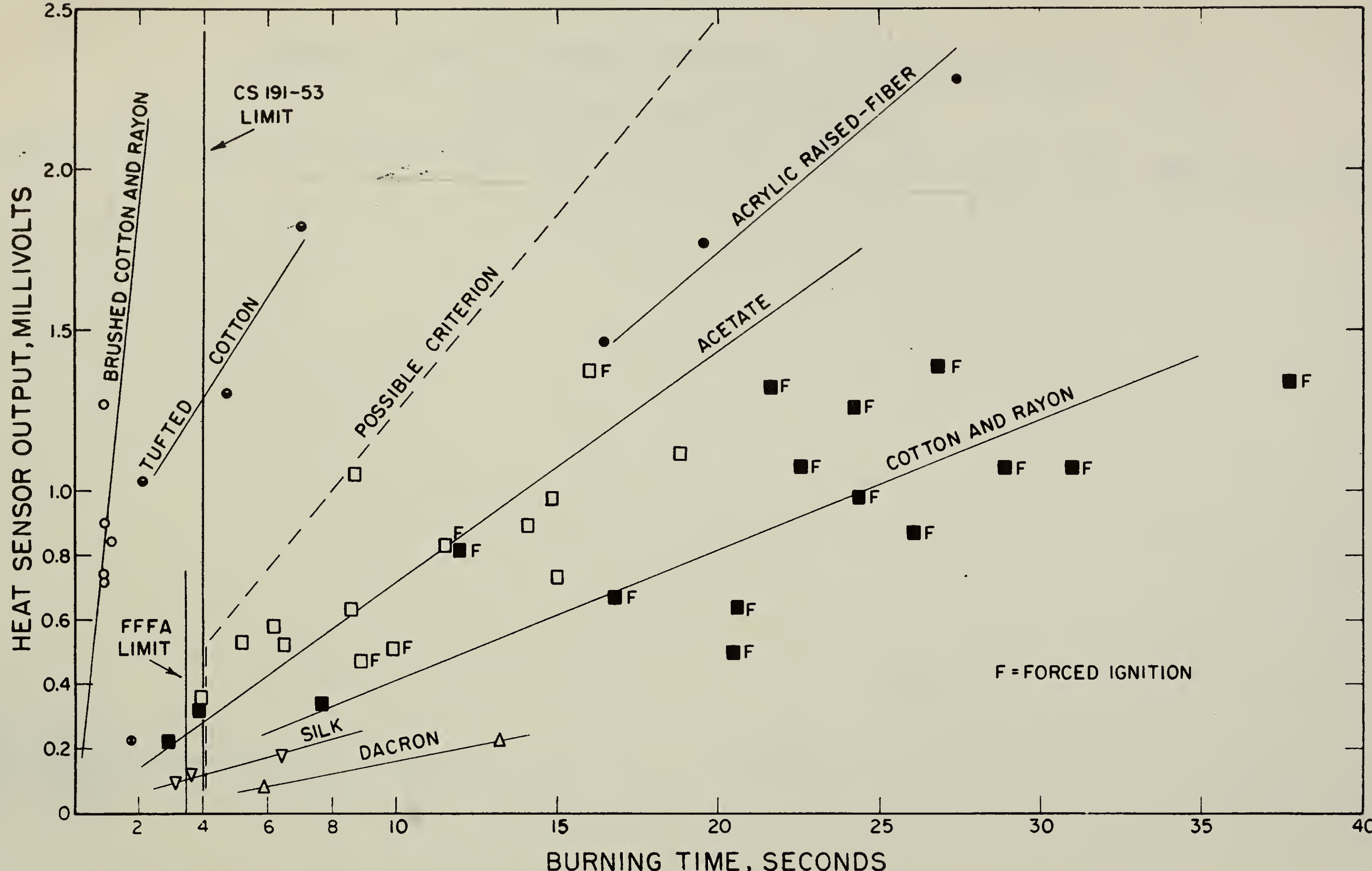

FIGURE 2. RELATION OF HEAT OUTPUT TO BURNING TIME

CS191-53 LIMIT - BURNING TIME BELOW WHICH A FABRIC IS DEFINED AS HAZARDOUSLY FLAMMABLE BY THE COMMERCIAL STANDARD.

FFFA LIMIT - BURNING TIME BELOW WHICH A FABRIC WITHOUT RAISED-FIBER SURFACE IS DEFINED AS HAZARDOUSLY FLAMMABLE BY THE FEDERAL FLAMMABLE FABRICS ACT

○ BRUSHED COTTON OR RAYON SHOWING SFBB (SURFACE FLASH, BASE BURNING)

⊗ RAYON PILE SHOWING TSF (TIMED SURFACE FLASH)

◒ TUFTED COTTON

● BRUSHED ACRYLIC OR ACRYLIC PILE-COTTON BACK

□ ACETATE OR MIXTURE PREDOMINANTLY ACETATE OR DACRON

■ COTTON OR RAYON (PREDOMINANTLY)

△ DACRON

▽ SILK

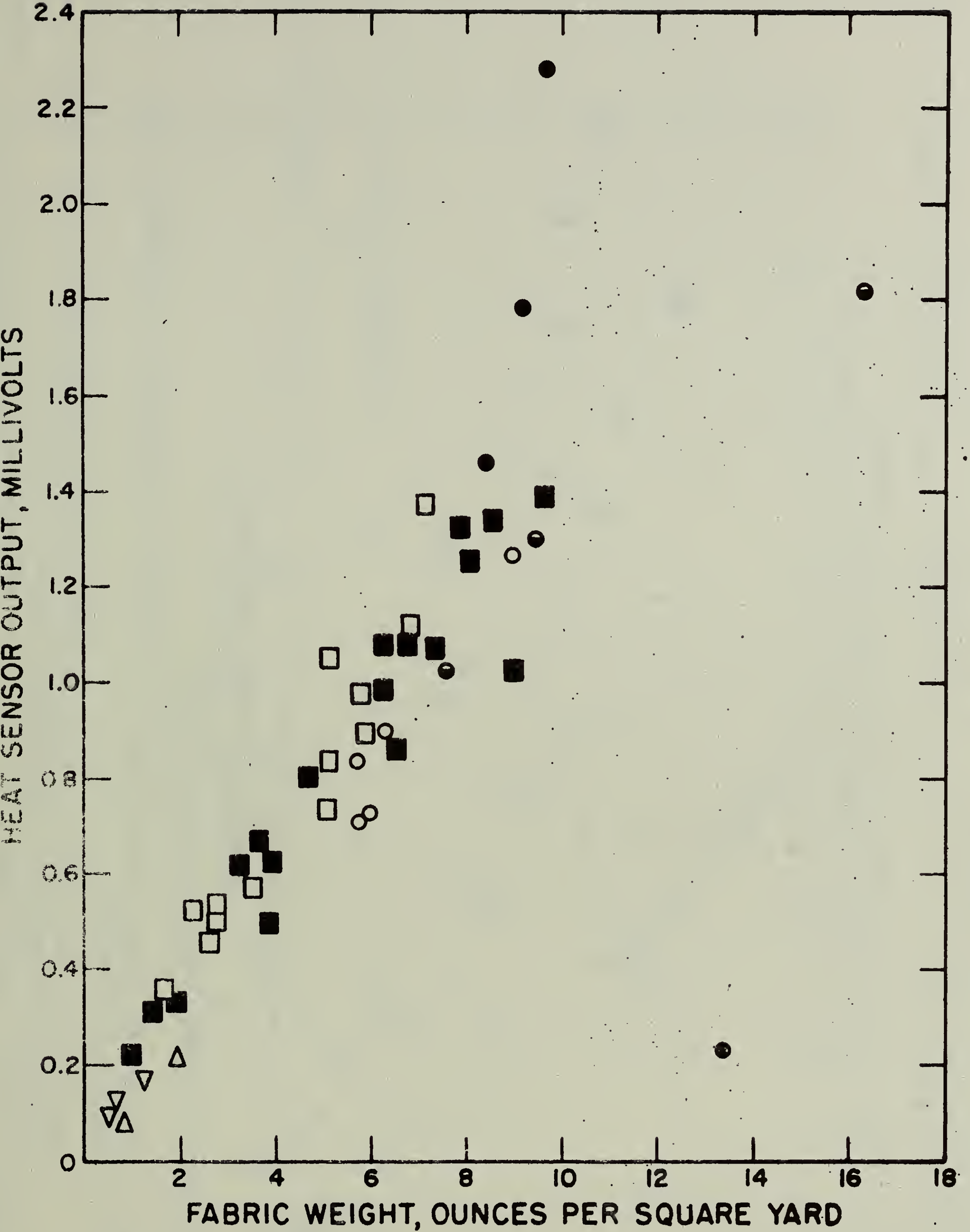

FIGURE 3. RELATION OF HEAT OUTPUT TO FABRIC WEIGHT

○ BRUSHED COTTON OR RAYON SHOWING SFBB (SURFACE FLASH, BASE BURNING)

⊗ RAYON PILE SHOWING TSF (TIMED SURFACE FLASH)

◒ TUFTED COTTON

● BRUSHED ACRYLIC OR ACRYLIC PILE-COTTON BACK

□ ACETATE OR MIXTURE PREDOMINANTLY ACETATE OR DACRON

■ COTTON OR RAYON (PREDOMINANTLY)

△ DACRON

▽ SILK

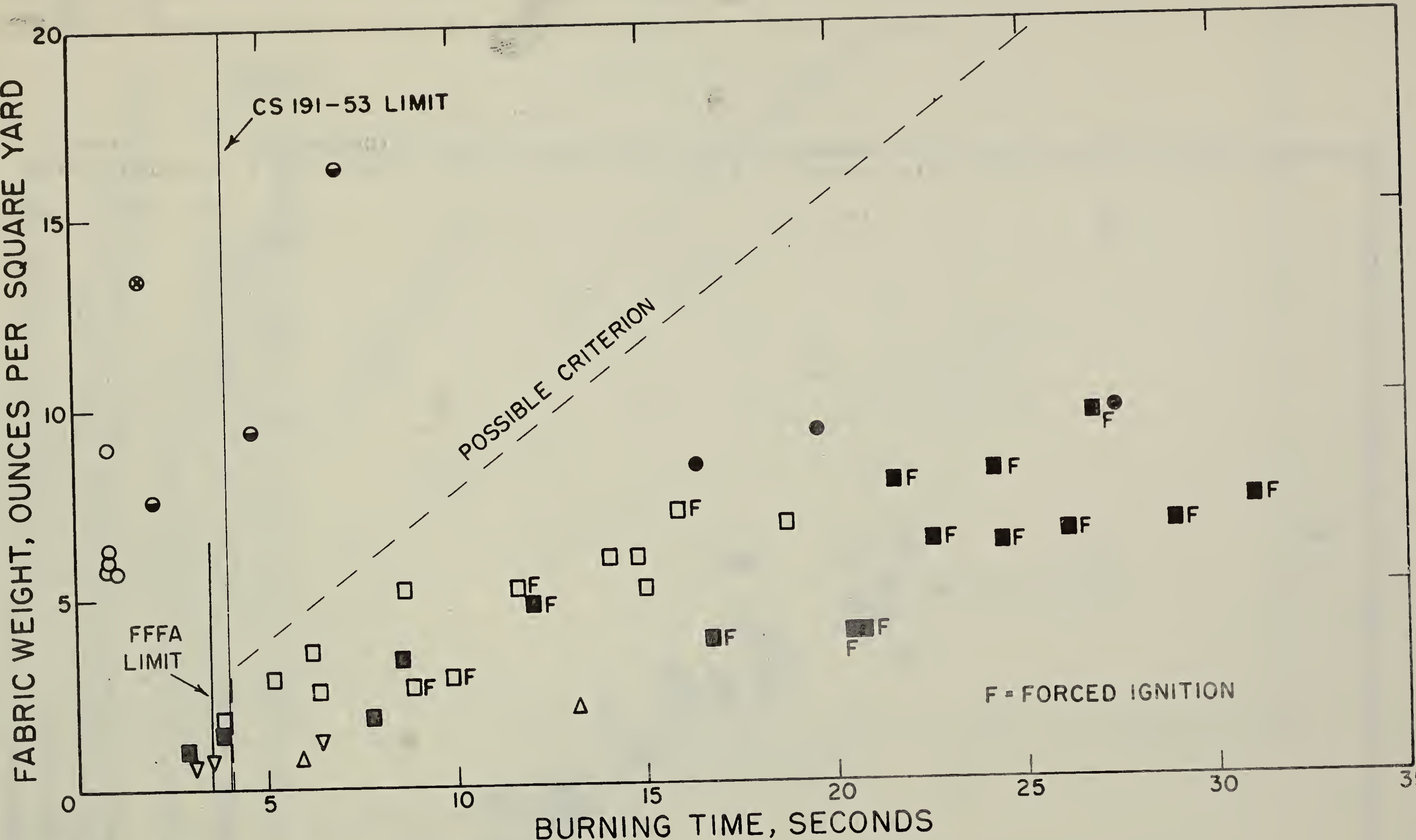

FIGURE 4. RELATION OF FABRIC WEIGHT TO BURNING TIME

CS191-53 LIMIT - BURNING TIME BELOW WHICH A FABRIC IS DEFINED AS HAZARDOUSLY FLAMMABLE BY THE COMMERCIAL STANDARD.

FFFA LIMIT - BURNING TIME BELOW WHICH A FABRIC WITHOUT RAISED-FIBER SURFACE IS DEFINED AS HAZARDOUSLY FLAMMABLE BY THE FEDERAL FLAMMABLE FABRICS ACT

○ BRUSHED COTTON OR RAYON SHOWING SFBB (SURFACE FLASH, BASE BURNING)

⊗ RAYON PILE SHOWING TSF (TIMED SURFACE FLASH)

◒ TUFTED COTTON

□ ACETATE OR MIXTURE PREDOMINANTLY ACETATE OR DACRON

■ COTTON OR RAYON (PREDOMINANTLY)

△ DACRON

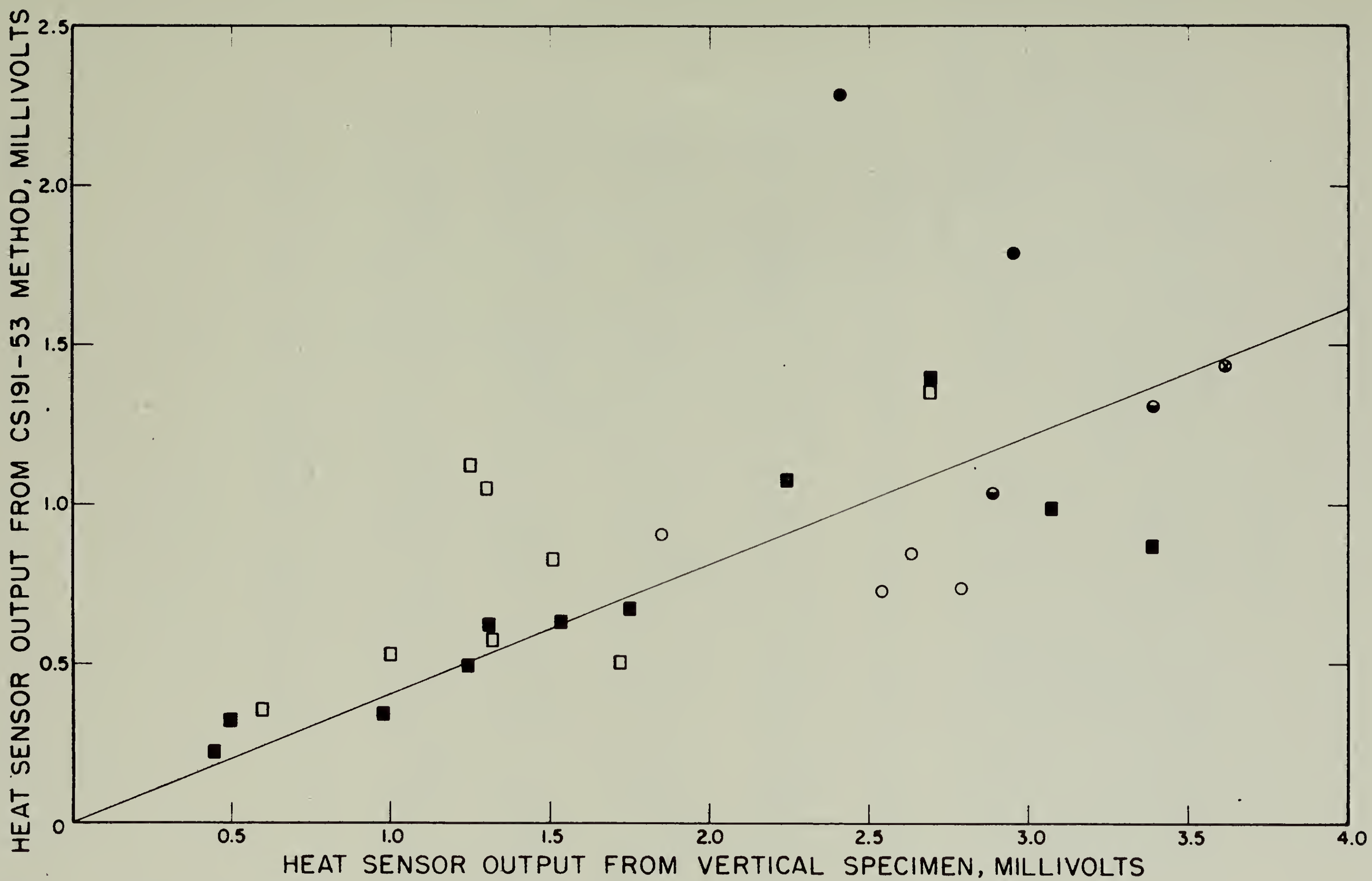

FIGURE 5. HEAT OUTPUT FROM CS191-53 TEST VERSUS HEAT OUTPUT FROM VERTICAL TEST

○ BRUSHED COTTON OR RAYON SHOWING SFBB (SURFACE FLASH, BASE BURNING)

⊗ RAYON PILE SHOWING TSF (TIMED SURFACE FLASH)

◒ TUFTED COTTON

● BRUSHED ACRYLIC OR ACRYLIC PILE-COTTON BACK

□ ACETATE OR MIXTURE PREDOMINANTLY ACETATE OR DACRON

■ COTTON OR RAYON (PREDOMINANTLY)

△ DACRON

▽ SILK

Appendix

It was evident that some of the variations which had developed in the application of CS191-53 resulted from changes in the manufacture of the equipment, which influenced the procedure although they did not violate the specifications of the standard. To avoid further such inadvertent modifications, it is recommended that the drawings be adopted as part of the commercial standard, or as a subsidiary requirement of the Secretary of Commerce, and that all future revisions should be subject to approval by the Secretary of Commerce. Before such adoption, however, it is recommended that the following clarifications and additions be incorporated in the drawings:

1. At the base of specimen rack (1) Drwg D453, change 3/8 dimension on 45° line to 5/16.

2. Revise thread guide (3) in right elevation, Drwg D453, of specimen holder assembly. There should be a tolerance on height of guides above top plate, perhaps ± 0.01 in.

3. Add additional thread guide, (10) of D453, to cabinet, D450, above thread spool, at a point 8-1/4" above floor and 5-1/4" from back. Include dimensioned positions for all thread guides.

4. Make counterweight (3) on Drwg D452 of brass or increase the size of steel weight to 1" dia x 1-1/2" long. (The specified dimensions in steel do not provide sufficient weight).

5. On Drwg D454, part 25, dimension of weight diameter is indicated as changed to 3/4 in. Current production, however, involves 5/8 in. dia weight as was used in our tests. This weighs about 33 gms. The weight should be specified.

6. The drawings should include dimensions of the flame length gage and the sheet metal specimen shim and block.

DEPARTMENT OF COMMERCE * NATIONAL BUREAU OF STANDARDS *